APPENDIX D
THERMAL DESORPTION PREDESIGN

1. Predesign. The site investigations and decision making process to render a decision regarding the choice for treatment should be completed prior to predesign. Further evaluations may be necessary to validate the decisions and to quantify the treatment criteria for the remediation contract. Other guidance documents address the RI/FS process.

2. Technology Evaluation. Information regarding site characterization, development of remediation goals, and choosing an alternative can be found in EM 1110-2-502, CEGS 02288, CEGS 02445, EM 1110-3-176, Cooper and Alley, Cross/Tessitore and Associates, and John Pinnion. The site investigation and feasibility study are essential in determining the appropriate technology to remediate the site. The first step in the process of investigating the site is to review all records of operating procedure and disposal practices. A summary of existing site-specific and local environmental information should be prepared. The local information will be used to evaluate surface, subsurface, and atmospheric pathways for contaminant migration and risk to receptors. The regional information would also help establish background conditions which could be helpful in deriving remediation goals for the site.

Once the data has been collected and compiled, the second step in the site investigation process is to develop a plan to identify the potential constituents of concern and site investigation activities. Depending upon the level of understanding of the site, the following is a list of activities which are typically included in a site investigation.

- Safety and Health Plan;
- Sampling and Analysis Plan;
- Non intrusive geophysical investigations;
- Sampling and environmental analyses;
- Soil and water (groundwater and surface water) sampling and environmental analyses onsite, up gradient of the site, and down gradient of the site;
- Air monitoring and sampling and environmental analyses;
- Water table measurements and aquifer characteristics;
- Unsaturated subsurface soil characterization;
- Ecological reconnaissance and impact studies; and

- Baseline risk assessment and contaminant fate and transport modeling.

The ultimate goal of the site investigation is to characterize the nature and extent of site contamination.

The next step in the site investigation process is to determine through a feasibility study the most appropriate remediation option for the site. The remediation can be as simple as installing institutional controls or as complex as excavation, treatment, and disposal of contaminated media. The technology used to remediate the site is dependent upon remediation goals developed for the site. Remediation goals are typically derived from the information presented in the baseline risk assessment and/or based on established cleanup standards and guidelines.

There are generally three phases involved in developing waste management option (remediation) during the feasibility study process:

- Identification of innovative/alternative technologies;
- Identification of all technologies which can treat/dispose of the waste stream;
- Development of alternatives for site remediation (it should be noted that an alternative will include all measures and phases required to remediate the site);
- Detailed evaluation of the alternatives with respect to effectiveness, implementability, and cost.

When completing an evaluation under Superfund regulations the effectiveness evaluation is expanded to include the consideration of the following RI/FS criteria:

- Over all protection to human health and the environment;
- Compliance with all applicable or relevant and appropriate regulations;
- Long-term effectiveness of the remediation;
- Reduction of toxicity, mobility, and volume of waste through treatment; and
- Short term effectiveness.

The remaining RI/FS criteria are not germane to an "effectiveness" consideration. The design team needs to focus on the five criteria during the effectiveness evaluation. The ultimate goal of this evaluation is to select an alternative which will cost effectively remediate the site while being protective of human health and the environment.

3. Evaluation of Site Characterization Data. Once the site investigation and feasibility study has been completed, the engineer must review the data presented in the study to identify any the data gaps. This is a critical step in the process since typically 4-5 years may pass between the completion of the remedial investigation and the start of the design process. It is the responsibility of the design team to fill the data gaps in the predesign phase.

3.1 Review. The design team should endeavor to conduct an objective review of the data. In the event the evaluator determines that a thermal desorber would be unable to achieve the remediation goals, additional data would need to be gathered in order to determine an appropriate management option. Table D-1 is a summary of the minimum physical and chemical data needed for the screening of thermal desorption.

3.1.1 Site Geology. Important geological characteristics to review are the soil classification, moisture content, and contaminant concentration in the soil. As discussed in Appendix C, waste up to 5 cm (2 inches) in diameter can be processed in a thermal desorber. Soil characteristics which may adversely impact the performance of a thermal desorption system include the following:

- High percent of clay or silts: results in high levels of fugitive dust emissions during handling. This includes soils which have a high percentage of fines which pass through the No. 200 sieve (75 micron size);

- Tightly aggregated soil: resulting in incomplete volatilization of contaminants from the soil;

- Rock soil or Glacial till: Rocks fragments interfere with processing;

TABLE D-1
Physical and Chemical Data Required
to Screen Thermal Desorption System

Parameter	Method
BTU/lb (Heat Content)	ASTM D240-85
Ash	ASTM D2974
Halides (Cl, Br, F)	300.0
Sulfur	300.0
Moisture Content	ASTM D2216-80
Nitrogen, Nitrates & Nitrite-N	353.2
Phosphorus	365.3
pH	SW 846 90451 150.1/ASTM D4972
Grain Size (soil classification)	ASTM D422M
Sieve (particle classification)	ASTM D2488-84
Total Organic Carbon	SW-846 Method 9060/415.1
TCLP	SW-846 Methods 1311, (3015, 3051, 6010, 7470, 7471, for Metals) 8260, for volatiles 3550, 3510A, 8270 for semivolatiles
Ignitability	101D (flashpoint, Pensley-Martens) or 1020 (Setaflash, Closed Cup)
Reactivity, Cyanide & Sulfide	9010 and 9030
Corrosivity	9040/9045 or 1110 (Coupon Method)
Atterberg Limits/(Plasticity)	ASTM D 4318-84

Source: ASTM, 1994. Annual Book of ASTM Standards, 1994, ASTM, Philadelphia, PA.
Columbia Analytical Services, Inc., 1993. Columbia Analytical Services, Inc. (CAS).
Price List effective March 5, 1993. Anchorage, AK.

- High moisture content: As discussed in Appendix C, there is a high energy input required to volatilize water. Dewatering may be required; and

- High plasticity: Materials can stick to the screening and conveying equipment. Clays, for example, are difficult to screen crush and will stick to thermal desorption equipment. Clays can also remold into large particles. Materials with a liquid index greater than one can not be processed in a thermal desorber without pretreatment (EPA, 1994).

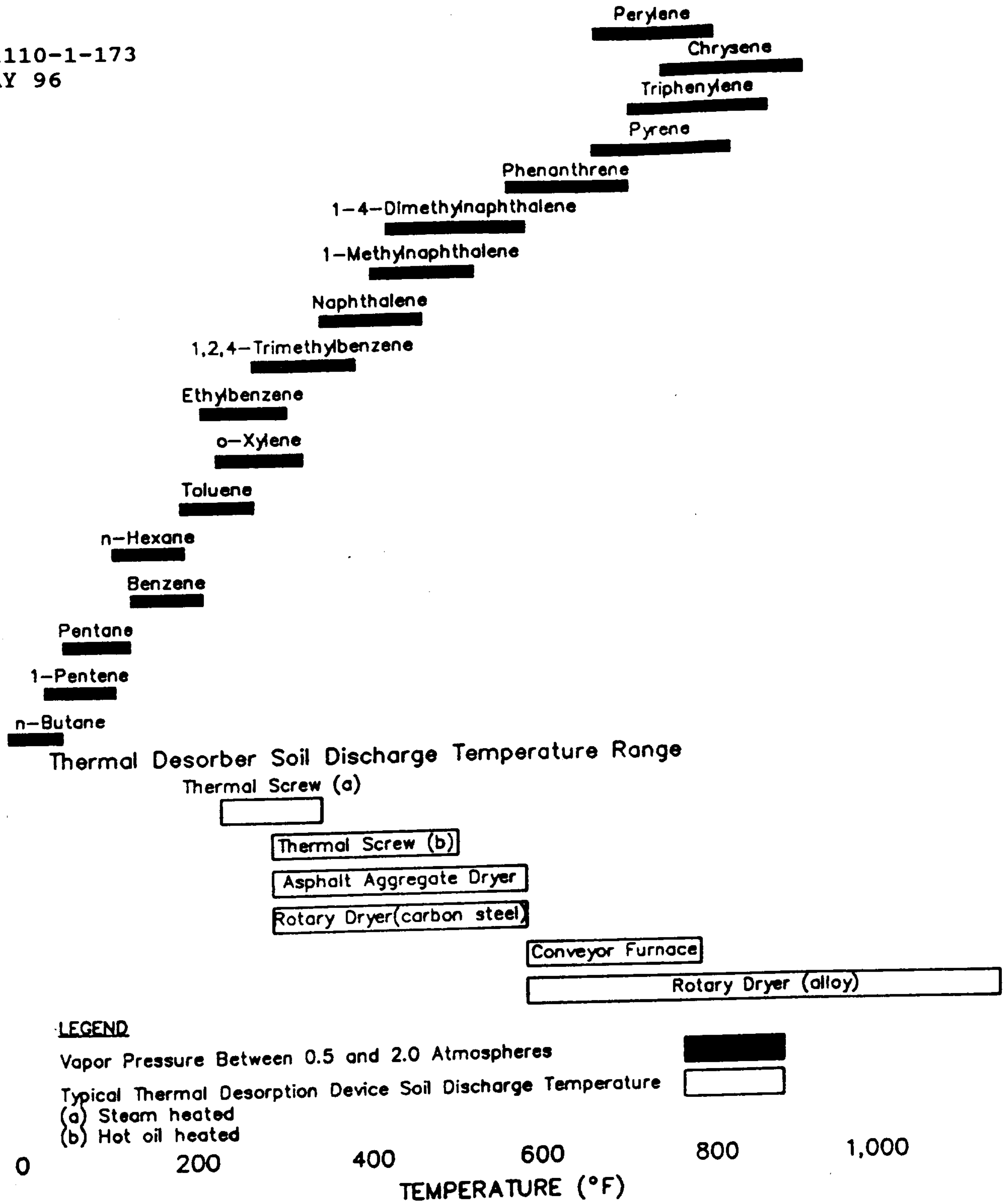
USACE Technical Manual Soils and Geology Procedures for Foundation Design of Buildings and Other Structures TM 5-818-1 provides additional information about soils and geology concerns.

3.1.2 Site Hydrogeology. The hydrogeologic conditions which can adversely impact a thermal desorption remediation process include the following:

- High water table or seasonal fluctuations of the water table;
- Subsurface clay lenses which can perch water or non-aqueous phase liquids;
- Karst terrain solution channels that can hold pockets of non-aqueous phase liquid.

These factors adversely impact the excavation and material handling of the soil. With any of the above conditions, the moisture content will generally be greater than normal (normal is considered to be 20% moisture). Pockets of non-aqueous phase liquids also can significantly increase the concentration of contaminant in the soil.

3.1.3 Contamination. Contaminants that have been desorbed and the theoretical vaporization temperature range of each are presented in Figure D-1. Table C-3 presented physical and chemical characteristics for chemicals listed in Figure D-1. Contaminated soils which are amenable to thermal desorption treatment include fine grained soils such as silts and clays,peat and most coarse grained sands. Coarse soils consisting of gravels are not amenable to treatment without prior crushing.



SOURCE:
U.S. EPA, 1994

FIGURE D-1

SOIL TREATMENT TEMPERATURES FOR SELECTED PETROLEUM HYDROCARBONS

3.1.4 Buried Materials. Excavation of buried materials (such as liners and covers from old landfills) is largely a materials handling issue. Prior to screening of soils, large debris such as rubber tires, car parts, foundations pieces would have to be separated from smaller debris in a separate staging area. 40 CFR 268.3, defines debris as solid material exceeding a 60 mm particle size that has been manufactured, or plant, or animal matter, or a natural geologic material. The large debris would be washed and, if necessary, hauled off site for disposal. Waste water would be collected and treated at the site wastewater treatment plant. Debris is considered to be hazardous waste if it exhibits toxicity characteristic for one or more of the constituents subject to U.S. EPA RCRA TCLP standards, or if it has been mixed with listed hazardous waste, or if listed hazardous waste is contained in the debris.

3.2 Supplemental Site Investigation. In situations where additional information is required to either better understand site characteristics or further delineate site contamination, supplemental site investigations may be necessary. This is particularly true if there has been a long period of time between the remediation investigation and the start of the design and/or if additional physical or chemical parameters need to be collected to confirm the thermal treatment option. Analytical data on metals is sometimes inaccurate for sites where the primary emphasis has been on organic contamination. Supplemental investigation activities generally fall into three categories:

- Identification and delineation of contaminated areas and depth of contamination;
- Additional characterization of contaminated material to establish performance criteria for thermal desorption; and
- Additional characterization of the site and contaminated material for characteristics which could interfere with, impede or reduce the effectiveness of thermal desorption remediation.

3.2.1 Identification of Supplemental Investigation Activities. The need for supplemental sampling and analysis will depend upon the data derived from the site investigation. If further delineation of the site wastes is required, sampling activities may include the following:

- Sampling to further delineate the aerial extent of contamination and establish the limits of the remediation area. Field screening can be used as a preliminary screen for contamination. A sampling grid or identification of hot spots is developed to determine where to collect environmental samples. The samples are generally collected at predetermined intervals until remediation goals are met.

- Sampling to determine the depth of contamination. Soil samples can be collected from soil borings or test pits to ascertain contamination depths in the remediation area. Samples are collected at regular and at various depths intervals until remediation goals are met or the water table is encountered (since contamination below the water table is generally considered a groundwater remediation issue).

If additional characterization of the contaminated material is needed, sampling activities will include collection of contaminated material samples to test for physical properties (moisture, grain size analyses, percent fines, etc.). Sufficient volume of representative soil samples, minimum twenty liters (five gallons), are generally collected using trowels and augers and are composited into a plastic lined 20 liter (5 gal.) pail.

3.2.2 Review of Analytical Data. Data are reviewed with regard to completeness of the package and compliance with the specified methodology. Care should be taken to note all method detection limits and to establish remediation requirements for the comparison. Some regulated sites have had remediation goals identified which were below the method detection limit. If this occurs, the EPA should be contacted to verify the method and detection limits and to discuss implementation of the remediation goals. Evaluations are performed according to project specific protocols contained in the Quality Assurance Project Plan (QAPP) incorporating the accepted analytical methods and produced in accordance with ER 1110-1-263 Chemical Data Quality Management for Hazardous Waste Remedial Activities.

3.2.3 Remediation Quantities Delineation and Estimates. Remediation quantities can be estimated by either using CADD or by hand calculations.

- Concentrations of the constituents of concern are plotted on a site plan. It is best to plot constituent concentrations for samples taken at the same depth.

- Concentrations on the site plan are compared with the remediation goals.

- Sample locations which exceeded the remediation goal are marked.

- Sample locations which are equal to and below the remediation goal are marked.

- The perimeter of the remediation site ,is established by establishing points halfway between locations above and those below the remediation goal.

- Lines that join the points to form boxes enclose areas that exceed the remediation goal. Samples that equal the remediation goal should fall near the lines.

Professional judgement will need to be exercised in areas of uncertainty. Once the areas have been enclosed, calculate the area requiring remediation. Multiply the area by the depth to obtain volumes for remediation. The volume is converted to tonnage by multiplying volume by the bulk density of the soil only when required for calculation. The material to be treated is defined by location.

Generally, classes of compounds are summarized by a single point. For example, when trying to determine the remediation area for polynuclear aromatic hydrocarbons, the toxic equivalent (developed in the risk assessment) of all the polyaromatic hydrocarbons is represented by a single number which is compared to the remediation goal. Once a supplemental investigation is completed and the site has been delineated, excavation quantities can be calculated by using CADD programs. USACE Standards Manual for U.S. Army Corps of Engineers Computer Aided Design and Drafting (USACE CADD) provides standards and procedures for use with CADD applications (EM 1110-1-1807).

In addition to using CADD applications and/or hand calculations, remediation quantities and excavation volume estimates can be determined using geostatistics coupled with three-dimensional data analysis. Geostatistics applications use measurements from one subsurface location to estimate the value at another sampled subsurface location. The correlation of two or more data location points is represented by a variogram (an equation of the graph of the expected square error of an estimate versus distance and direction). After definition of a variogram, a technique called kriging is used to estimate values at unsampled locations to produce a map of the sampled variable. The variables used in this type of geostatistical analysis include concentrations of constituents of concern and depth. Software packages are available which combine geostatistical analysis, variography and kriging for excavation estimates.

4. Identification of Data Gaps. Treatability studies are typically based upon a preliminary evaluation of soil/sediment technologies. The decision process used during the preliminary evaluation of technologies to determine the need for treatability studies consists of the following steps:

- Consider site characterization data gaps;

- Determine if the existing site data or literature is sufficient to evaluate the technology in detail;

- Determine if the site-specific data in conjunction with the available information on the technology is sufficient to determine the performance, operating parameters, and relative cost of the remedial technology; and

- Determine if a treatability study will reduce the uncertainty or risk of the use of a given technology to an acceptable level so that the best possible remedy can be selected.

Uncertainties associated with the applicability of thermal desorption include:

- The ability of the technology to reach the site-specific cleanup levels;

- Temperatures and solids retention times required to adequately treat the soils, and the energy requirements to hold and maintain these conditions;

- The impact of fine silts in the soils on the ability of the technology to adequately treat the soils;

- The moisture content of the waste;

- Removal of and potential emissions control requirements for metals;

- Impacts of high concentrations of PAH in the soils on the adequacy of treatment; and

- Because some thermal desorption technologies are non-destructive, the characteristics of the residuals, and subsequent management requirements, are uncertain.

Metals will not be adequately treated by thermal desorption. The thermal desorption process could alter the condition of the treated soils (e.g., concentrate metals) and possibly require the implementation of metals control technologies, such as stabilization of residuals.

5. Recommendations for Treatability Studies. Prior to the selection of thermal desorption as a remediation technology, treatability studies are required for the following reasons: to ensure that a selected treatment technology is applicable for waste characteristics; to ensure that cleanup goals can be obtained, and to provide data which supports the selection and implementation of the remedial alternative. Implementation of treatability studies for thermal desorption applications addresses the five RI/FS primary balancing criteria:

- Overall protection of human health and the environment;
- Compliance with applicable or relevant and appropriate requirements (ARARs);
- Implementability;
- Reduction of toxicity, mobility or volume;
- Short term effectiveness;
- Cost; and
- Effectiveness.

Appendix J includes a treatability study scope of work. Additional information required includes a description of a typical treatability unit, data to be collected from the unit, methods to analyze data, and procedures for extrapolation of this data for either the system design and or the operation of a full scale unit.

Three levels of treatability studies exist which are: remedial screening, remedial selection and remedial design. Remedial screening treatability studies establish the ability of the technology to treat a waste and typically, have a low cost ($30,000 in 1994 dollars). Remedial selection treatability studies identify technology performance for a specific site and require higher precision with increased QA/QC for sample handling and analysis. Remedial design treatability studies provide quantitative performance, cost and design information for a specific thermal desorption unit. Remedial screening treatability study tests provide the following information: temperature, treatment times, initial contaminant concentration, and treated contaminant concentration. Selection type treatability studies provide the following information: expected full scale through put, material handling system design requirements, air pollution control system design requirements, and requirements for air pollution control measures during excavation, preparation and handling (Cross/Tessitore and Associates, P.A., 1993).

Each of the three levels of treatability studies must be incorporated into both the project schedule and budget at the onset of a remediation project. Initiation and planning of treatability studies can begin as early as the site characterization phase of a project and continue through the technology screening and into the remedial design phase of a project. However, treatability studies are not required when data on similar applications of the technology is available (Cross/Tessitore and Associates, P.A., 1993).

The level of quality assurance (QA) and quality control (QC) increases accordingly throughout the treatability studies process. Since the remedial screening phase of a treatability study is concerned primarily with the ability of a technology to treat a waste, analytical requirements are focused on representative indicator parameters (such as most common contaminant or most hazardous). Remedial selection treatability study analytical requirements will require more stringent QA/QC requirements. QA/QC requirements during the remedial selection testing could require duplicate or triplicate analysis to confirm reproducibility and verification of meeting established cleanup goals (Cross/Tessitore and Associates, P.A., 1993). For more specific information regarding data quality and quality control, refer to ER 1110-1-263 Chemical Data Quality Management for Hazardous Waste Remedial Activities and CEGS 01450 Contractor Chemical Data Quality Control.

Thermal desorption treatability studies can be conducted in either a laboratory or field setting. Laboratory equipment available for laboratory treatability studies includes muffle furnace equipment and rotary quartz kiln applications. Muffle furnace equipment provide a rudimentary general determination of the ability of thermal desorption to adequately treat a specific waste stream, whereas rotary quartz kiln applications are more suitable for the remedial selection level of treatability studies. Other types of thermal desorption equipment which can be used for treatability studies include static tray tests, differential bed reactors (DBR), fixed bed reactor, rotary kiln simulators which depending on site specific concerns, could be used for on-site pilot scale demonstrations (Cross/Tessitore and Associates, P.A., 1993).

Typically, the treatability study objective determines the sampling and analysis requirements during a thermal desorption treatability study. Prior to any treatability study activity, a site specific sampling plan consisting of sample location, depth, collection technique and homogenization procedures should be in place. Treatability sampling of identified hot spots is typical if the treatability study is focused on testing the technology ability to handle worst case contaminant concentrations. Composite samples (average samples for an entire site) are collected when the test objective is determine the ability of the technology to treat a representative homogenous waste (Cross/Tessitore and Associates, P.A., 1993).

Treatability studies are primarily conducted to reduce the uncertainties discussed in the previous paragraph. Typically testing can be performed by using bench scale or pilot scale techniques. Bench scale testing is usually performed in a laboratory, in which comparatively small volumes of contaminated material are tested for individual parameters. Presented below is a description of different types of treatability studies.

5.1 <u>Bench Scale Tests</u>. Thermal desorption bench-scale data is generally used to establish the viability of the technology to treat various contaminated materials. The data will also provide some approximate cost information and operating conditions for the technology. Positive bench scale test results indicate that a technology is feasible, subject to scale-up and materials handling limitations. Negative results are generally inconclusive; Additional pilot scale testing is generally necessary to confirm a technology's effectiveness and/or provide design data if it is selected for implementation.

Typical goals of the bench scale treatability study would be to:

- Make an initial determination of the ability of the technology to reduce concentrations under site-specific conditions;

- Provide initial input into the determination of energy and utilities requirements for full scale operations; and

- Provide initial input into system design parameters, such as required solids retention times and temperatures, thereby making possible estimates of treatment rates and clean-up cost estimates.

The results of these tests should establish the effectiveness of thermal treatment to reduce concentrations of the contaminants in the soil under laboratory conditions and the likely operating conditions necessary to achieve this removal.

Bench scale test equipment used for thermal desorption include a muffle furnace, or rotary quartz kiln/tube. Conceptually, small quantities of the soil samples will be exposed to a contaminated material of temperature and residence times in a rotary quartz kiln tube or muffle furnace. These temperatures and residence times represent operational range typical of commercial thermal desorption systems. Treated soils will then be analyzed to determine the effectiveness of the treatment. Parameters to be determined in comparing treated versus untreated soils would be:

- Concentrations of individual contaminants; and
- Loss of total organics.

Rotary quartz tube kilns are also used as bench scale devices for thermal desorption applications. This system utilizes a rotary batch quartz kiln, a drive motor, and temperature controls. Soil samples are placed into a rotating quartz kiln while the temperature of the medium is uniformly maintained by a temperature control system. Process gases generated from thermal desorption unit processes are passed to a thermal oxidation unit, condensers or a carbon adsorption column. Data such as temperature, retention time, system pressure and process gas composition can be monitored and recorded during bench scale testing (Hazen Research Inc.,1994).

Advantages of using rotary quartz tube kiln devices for thermal desorption bench scale testing include the following: simulation of soil mixing and system turbulence (found in rotary dryer applications); measurable, controllable and recordable temperatures and retention times throughout testing; and process gas composition and emissions can be determined and analyzed (Quinn Process Equipment, 1994).

Muffle furnace devices used for bench scale testing offer significant initial cost advantages (the cost of muffle furnace equipment(~$2000-3000 in 1994 dollars) is significantly cheaper than a rotary quartz tube kiln system (~$17000 to 20000 in 1994 dollars), however data generated from a rotary quartz kiln test is typically more complete and representative of full scale treatment, allowing for better estimates of treatment costs, times and temperatures.

5.2 Pilot Scale Tests. Pilot scale tests are intended to simulate the physical and chemical parameters of a full scale process. The volume of soil required for a pilot scale unit is much greater than that for a bench scale tests. Pilot scale tests are intended to serve as a practical testing approach for full scale operation.

Pilot units operate in a manner as similar as possible to the operation of a full scale system. Most contractors of thermal desorption units have pilot scale systems which are used to determine the design and operation criteria for a successful system operation. Examples of information provided from pilot scale testing include:

- Effects of mixing on the system;
- Off-gas emissions expected from the system; and
- Actual power requirements for the system.

The Waterways Experiment Station (WES) has a pilot scale thermal screw that may be available.

6. Treatability Test Run. A treatability test run utilizing a rotating quartz kiln system can substantiate the selection of thermal desorption as the remediation process. Results of a treatability test run can include information regarding materials handling, feed systems, temperature, retention time, system pressure, and process gas composition. A rotary quartz kiln system allows for the soil sample temperature to remain uniform. Process gases exit the kiln to either a thermal oxidation unit, condensers or a carbon adsorption column for decomposition or collection of vaporized contaminants.

6.1 Treatment Temperature. As discussed in the previous paragraph, the thermal desorption treatment temperature is a function of several parameters:

- Particle size of the soil;
- Moisture content;
- Heat capacity of the soil;
- The temperature range which the organics will

desorb; and

- The heat transfer and mixing characteristics.

As the solids progress through the reactor, they are processed in the follow zones:

- Warming Zone - soil is heated to the boiling point of water 100°C (212°F);
- Drying Zone - soil is maintained at 100°C (212°F) until the moisture has evaporated;
- Heat Up Zone - soil is heated from 100°C (212°F) to the target treatment temperature; and
- Holding/Treatment Zone - soil is processed at or above the target temperature to desorb the organic.

It is important to remember that the energy required to heat the soil will be substantially greater than heating only the water (without evaporating it) contained in the soil.

6.2 Residence Time. Residence time for soils in a thermal desorber system is a function of the shape of the treatment unit, rotational speed of the soil conveyor (shell or auger) and the angle of the treatment unit (U.S. EPA, 1994, EPA/540-594/501). Typically, soil residence times range from 3 minutes to over an hour (U.S. EPA, 1994, Troxler, et. al., 1993). Based upon results generated from treatability studies, information such as time of treatment and corresponding temperature to meet clean up levels for particular contaminant(s) can be included in the contract specifications.

6.3 Organic Removal Efficiencies. Organic removal efficiencies of the thermal desorption test run are calculated using the following equation:

$$\text{Organic Removal Efficiency (\%)} = \left(1 - \frac{\text{(Organic Concentration after Treatment)}}{\text{(Initial Organic Concentration before treatment)}}\right) \times 100\%$$

where organic concentrations are expressed as a dry weight basis.

Removal efficiencies are typically greater at high temperatures; at low temperatures, removal efficiency is dependent on the volatility of the organic compound.

Residence times required are also reduced at higher temperatures.

6.4 <u>Corrosive Effects on Selected System</u>. Corrosive effects on a selected thermal desorption system are dependent on the type of purge gas used (oxidative or inert), on the type of thermal desorption system utilized (direct fire or thermal screw), and on the contaminants present in the soil.

Typically, combustion gas from the burner of a direct fire unit serves as a purge gas. The allowable organic content of the soil in a direct fire system is limited due to the excess oxygen contained in the purge gas and the potential of supporting combustion within the unit. Thermal screw systems operating with an inert gas such as nitrogen can treat soils and sludges with higher organic concentrations due to limited presence of oxygen to support combustion.

Contaminated materials containing chlorinated and fluorinated hydrocarbon as contaminants can create hydrochloric and hydrofluoric acids during treatment. The acids will develop because of the volatilization of sulfides, chlorides and fluorides and evaporation of soil moisture in the unit causing corrosive damage to the carbon steel structures present within the treatment unit.

6.5 <u>Energy Input Required</u>. Energy input required for a thermal treatment desorption treatability test run is energy required to heat the thermal device used to simulate thermal desorption unit (oven, furnace, incinerator, asphalt mixing plant) and energy requirement for the off gas collection device (hood, vent, vacuum). Power requirements for hoods and vents comprising the off gas collection device are directly related to the product of the fluid pressure loss multiplied by the volumetric flow rate for the system in watts (ft-lb/min). The relationship is valid provided the volumetric flow rate and pressure loss are determined at the same conditions within the off gas collection device. Fans provide required energy to move gas and air through the hoods of the collection system. Fan performance is indicated on "fan curves" which identify the relationships between airflow, static pressure delivered, mechanical efficiency, and brake horsepower (Cooper and Alley, 1986).

Energy input required for a full scale thermal desorption treatment system is a function of operating temperature, retention time, type of system (direct fire, indirect fire, or thermal screw) and the extent of air pollution control/emissions equipment present on a full scale system.

6.6 Suitability of Treated Materials for Backfill or Disposal Purposes. The use of thermally treated materials for backfill purposes is primarily a function of the material characteristics, specifically, in the case of soils, the USCS Soil Classification and moisture content. The most suitable soil type for use as backfill would be those coarse grained soils (SW, SP, SM, SC) with low moisture content because of minimal pretreatment requirements and good heat transfer characteristics. Materials not suitable for backfill would be fine grained soils ML, OH, MH, CL, and Pt. These materials would reduce system capacity due to particulate carry over (U.S. EPA, 1994a).

Specifics regarding suitability of soils for desorption, backfill operations, USCS Soil Classification, and soils stabilization/solidification can be found in the following Army Corps of Engineers Documents:

CEGS 02228 Remediation of Contaminated Soils and Sludges by Incineration
CEGS 02445 Solidification/Stabilization of Contaminated Material
ETL 1110-1-158 Treatability Studies for Solidification/Stabilization of Contaminated Material
TM 5-818-1 Soils and Geology Procedures for Foundation Design of Buildings and Other Structures (except Hydraulic Structures)
TM 5-818-4 Backfill for Subsurface Structures

6.7 Presence of Volatile Metals. Volatile metals such as arsenic, mercury and lead may be removed from the soils during thermal desorption treatability test run. Recovered particulate and organics from a treatability test run can contain elevated concentrations of volatile metals such as mercury, arsenic and lead. The treated soils may contain concentrated levels of metals due in part to the volume loss as a result of volatilized organics. Soil treatment may increase the leachability of metals and the potential for failure of the toxic characteristic leachate procedure (TCLP) analysis.